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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

In the Matter of	)	
	)	
Replacement of Pat-t 90 by Part 88 to Revise the Private Land Mobile Radio Services and Modify the Policies Governing Them	))))	**PR Docket No. 92-235**

REPLY COMMENTS
OF
DR. GREGORY M. STONE & ASSOCIATES

DR. GREGORY M. STONE & ASSOCIATES, is pleased to submit the attached Reply Comments in response to the Federal Communications Commission's Notice of Proposed Rule Making, in the above captioned proceeding.,

Respectfully submitted,

30 JULY 1993

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[1] Notice of Proposed Rule Making, PR Docket No. 92-235, 7 FCC Rcd 8105 (1992)

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July 30, 1993

I. QUALIFICATION STATEMENT OF DR. GREGORY M. STONE

Dr. Gregory M. Stone is a consulting scientist and Principal of Dr. Gregory M. Stone & Associates of Alexandria, Virginia. Dr. Stone holds a Ph.D. in Electrical Engineering and has in excess of sixteen years experience in the area of wireless communications technology with concentration in both terrestrial and aeronautical systems. Dr. Stone is a member of the Institute of Electrical and Electronic Engineers and currently serves as Chairman of the Vehicular Technology Society's Propagation Committee. In addition, he is a member of the Radio Club of America and was awarded the status of Fellow in 1985 for his work performed in the areas of bandwidth and spectrally efficient wireless technologies. Over the past sixteen years Dr. Stone has served as a communications and technology consultant to a number of federal, state, local, and international public safety entities and to several large regional telephone companies cellular/mobile communications subsidiaries. In addition, Dr. Stone currently serves as a member of the Editorial Advisory Board for Mobile Radio Technology and as a Member of the Executive Committee of the IEEE International Carnahan Conference on Security Technology - Electronic Crime Countermeasures. Dr. Stone is the author Of in excess of sixty (60) professional papers and reports dealing with technology related issues. Dr. Stone has served as an expert witness in the area of science and technology for a U.S. Government agency before the U.S. Congress.

The statements contained and opinions expressed in this filing are solely those of Dr. Gregory M. Stone and do not necessarily reflect those of any professional association, organization or client entity he is currently, or was previously, affiliated with.

II. SUMMARY REPLY COMMENTS

Although many of the issues associated with the spectrum refarming issue are technologically intense, they are neither insurmountable nor beyond the scope of the current art.

Today, in 1993, we have a golden opportunity to develop a forward looking proactive yet evolutionary strategy that will accommodate this nations ever expanding wireless communications and information transport requirements well past the turn of the century.

In reply to comments filed in this Notice of Proposed Rule Making, we address the following specific points:

> The Commission should recognize that narrowbanding, per se, is NOT an impediment to the efficacious future use of wireless multimedia digital services.
>
> Future digital multi-media services (NCIC 2000, telephoto) are not voracious consumers of bandwidth as some incorrectly state but rather may impose demanding requirements on information transport capacity.
>
> In bandwidth limited channels the information transport capacity is a function of channel coding efficiency (bandwidth efficiency), and power, not of bandwidth as many incorrectly assert.
>
> Recognizing the science of bandwidth efficient technologies, the Commission should establish power and antenna height limitations that ENCOURAGE the proliferation of bandwidth and spectrally efficient technologies.
>
> The Commission should allow **100%** occupancy of 6.25 KHz authorized bandwidth, subject to certain technical caveats
>
> The Commission should require, as a precondition of type acceptance, disclosure by manufacturers of certain technical details need to facilitate frequency coordination of systems employing disparate modulation and channel access techniques

The Commission should provide for an extended migration period only for Public Safety spectrum users.

The Commission should mandate 6.25 KHz narrowband channels on ALL existing Part 90 frequency bands above 30 MHz.

The Commissions should provide for the accommodation of engineering studies to support unique spectrum usages that are otherwise not provided for

Let there be no misunderstanding of our position. We emphatically support innovation and technological advancement. We believe that the mandate of narrowband technologies is in the public interest and will ultimately result in greatly increased spectral use efficiency.

III. INTRODUCTION

We have reviewed a number of initial comments filed by various parties in the NPRM. We are concerned with the overall negative bias of these comments. For example some commentators refer to the 5/6.25 KHz proposal as Very Narrowband when in reality should be addressing the proposal in terms of very bandwidth efficient. Furthermore, in many instances, under the guise of "technical" or "economic" objections many comments condemn the entire narrowbanding concept and appear only to serve to frustrate the promotion of increasing spectral use efficiency for the land mobile services.

In response to these comments we have elected to focus on certain critical aspects we hope will provide both a rebuttal to technically incorrect information and to address those issues that we believe are essential considerations if true technological innovation is to be stimulated and improved spectrum use efficiency attained.

IV. NARROWBANDING vs. FUTURE DIGITAL SERVICES

We believe that a critical yet often stated misinformation be corrected concerning the impact of narrowbanding of spectrum and its ability to support multimedia digital services.

Many commentators have incorrectly asserted that reducing channel bandwidth reduces the information capacity of the channel. This is not true. Likewise these same parties assert that future multimedia digital services will require “increasing amounts Of bandwidth”. This notion is absurd and represents a fundamental lack of understanding.

What exists today is a continuing confusion over bandwidth (how many Hertz wide a channel is) and the INFORMATION TRANSFER capacity of a channel.

Future multimedia digital services will likely demand greater information transfer capacities, NOT increased bandwidth.

Unfortunately, this issue is not trivial and gets to the root of much of the opposition to the Commissions narrowband proposals. Likewise, the land mobile community is inundated with marketing hype today from manufactures who use bandwidth as the magic potion needed to support wireless multimedia services.

The Commission must not let itself be deceived by this hype but most focus on the scientific facts appertaining to the underlying physics of the narrowband/bandwidth efficient technologies themselves.

In the wireless world, spectrum (bandwidth?) is a precious and limited resource that must be used correctly and efficiently. To accommodate ever increasing demands for higher and higher information transfer rates, attention must be directed to the judicious application of BANDWIDTH EFFICIENT technologies. That is, to technologies which efficiently utilize bandwidth.

We must state however, that narrowbanding does result in demonstrative improvements in bandwidth efficiency AND spectrum use efficiency if properly implemented. However, we also advocate the use of broadband techniques such as Pseudo Noise Direct Sequence Spread Spectrum/Code Division Multiple Access and Frequency Hopping (PN-DSSS, CDMA, FH). We suggest that for today, the most realizable approach is through employing frequency division narrowband as the comparative efficiency metric. Later, assuming an open regulatory posture, in time we believe the real future is hybrid very narrowband FDMA i.e. with information bandwidths equivalent to analog linear voice 3.125 KHz, having types of **PN-DSSS** and **FH** system overlaid. This notion is discussed later in our comments.

The Commission has recognized the need for spectrum resource conservation and improved efficiency. Mandating narrowbanding is an essential element to promote this goal however narrowbanding unto itself is ineffective without the regulatory flexibility that encourages advanced technology implementations.

There is no real mystery to bandwidth efficiency as the science behind it is straight forward. According to Shannon, in situations where bandwidth is limited, a more sophisticated channel coding(modulation) is required that requires more POWER per unit bandwidth. Thus, if the Commission is serious about improving spectrum use efficiency, it must link power level authorization to bandwidth efficiency. Thus, a more bandwidth efficient technology would be allowed to employ greater power levels than relatively less bandwidth efficient technologies.

In all of the excitement surrounding the wireless digital revolution, often one looses sight of the basic principles that dictate what and how well techniques will perform in the physical world. Whilst adequate space is not available to exhaustively address the Nyquist theorem or the Shannon Channel Capacity Theorem, certain principles, fundamental to our discussions here, must be restated.

Nyquist stated that the theoretical minimum bandwidth needed to transmit x symbols per second without inter-symbol-interference (ISI) is $x/2$ Hz, representing a basic and fundamental constraint. With the advent of digital signal processor based "brick wall" filters, one half symbol rate bandwidth occupancy is becoming more practicable where in the past the rule was that a double sided Nyquist bandwidth of x Hz was resulting in 1 symbol per second per Hertz bandwidth (1S/s/Hz). Even with that constraint, dramatic bandwidth efficiencies may be obtained as discussed below, but at a cost.. .additional power.

In the digital process, efficient digital transmission may occur if the source data and channel employ proper coding techniques. In this context coding refers to the number of bits that may be "coded" onto one symbol as defined by Nyquist. This is the basic fundamental behind bandwidth efficient modulation. Assuming proper coding is employed, a channel of W Hz bandwidth has a capacity C, for various RF carrier-to-noise ratios (CNR) which may be determined via the Shannon Channel Capacity theorem which is contained in the following expression:

$$C = W \log_2 (1 + CNR)$$

From this equation, assuming carrier-to-noise ratios of 1 dB through 18 dB correspond to the maximal bandwidth efficiency values with perfect coding are presented in Table-1 that follows:

TABLE-1

Bandwidth Efficiency Value	Required Carrier-to-Noise Ratio (CNR)
2.0 b/s/Hz	5.0 dB (3.15)
3.0 b/s/Hz	8.0 dB (6.3)
4.0 b/s/Hz	12 dB (15.8)
5.0 b/s/Hz	15 dB (31.6)
6.0 b/s/Hz	18 dB (63)

Note: These values reflect rounding.

A channel with an occupied bandwidth (consistent with proposed authorized bandwidths of 4.0 and 5.0 KHz respectively) 4.0 KHz wide, with an RF CNR of 25 (14 dB which is very typical in land mobile radio) would have a theoretical data rate capacity of 18.8 kb/s, which equates to a bandwidth efficiency of 4.7 b/s/Hz. At an occupied bandwidth of 5.0 KHz channel information rate increases to 23.5 kb/s.

Unfortunately, in today's practice, it is not possible to obtain the full theoretical Shannon channel capacity. But still, it is possible to employ channel coding, and to fully exploit advances in DSP based filtering that permits highly efficient use of bandwidth which may closely approach the capacity limit defined by Shannon.

This is true not only for the modulator/transmitter but also for the detection and demodulation systems. Many DSP based techniques are available to mitigate the increased phase distortion and differential delay susceptibility inherent in bandwidth efficient techniques. In fact, techniques exist that are able to effectively normalize desired-to-undesired performance that may facilitate frequency coordination and reuse. Of course, this imposes certain levels of complexity on very bandwidth efficient techniques but a cost/performance trade-off can be made that is market demand driven, not technical.

What is important to note is the relationship between information capacity, bandwidth and power. The Shannon theorem indicates that the easiest means to increase channel information capacity is by increasing bandwidth W, and the most difficult means to increase channel information rate is by increasing power. Power increase is at a disadvantage as channel capacity only increases with the logarithm of power.

Thus, one is faced with two and only two fundamental choices: If one desires to limit power one must increase bandwidth; or, if one desires to limit bandwidth one must provide for increased power.

With this in perspective, keep in mind the proposals currently being advanced by the Commission and other regulatory bodies to restrict bandwidth and to limit power, ostensibly to promote increased bandwidth and spectral efficiency.

Of course, binary signaling such as 2-PSK, 2-FSK, or 2-ASK, is limited to an information bit rate of 1 .O b/s/c/s under ideal conditions. This is due to the fact that the bit rate and the baud symbol rate in binary systems are equivalent; and in order to avoid inter-symbol interference, as promulgated by Nyquist, two symbols (0,1) per given unit time is the maximum transmission rate with binary techniques. Because of this, some type of high-level (m-ary) channel coding is needed to increase the information transfer rate per symbol transmitted. Thus, with m-ary signaling, increased information rates are possible while conserving bandwidth, at the expense of Carrier-to-noise ratios. Because land mobile is not a “power limited” service, it is prudent to trade power efficiency for efficient bandwidth and spectral utilization.

The key to effective exploitation of bandwidth efficiency, assuming that adequate power is permitted, is though the use of multi-level (m-ary) modulation/coding in which many information bits are encoded into each symbol transmitted. Thus, while in binary systems the information bit rate is equivalent to the transmitted baud rate, with m-ary coding, the information rate conveyed is higher than the symbol baud rate. We believe that today, in 1993, the most promising m-ary technique is that of Quadrature Amplitude Modulation (QAM). With these techniques, bit rate capacity is determined by the number of phase and amplitude levels. It is interesting to note that much publicity recently has been directed at pi/4 QPSK modulation. In reality, such is a form of QAM and as such represents the entry level into the bandwidth efficient modulation domain. The bandwidth efficiency in terms of bits per second per hertz bandwidth (b/s/Hz) is a function of the coding level employed. In this discussion we are assuming that the coding and information transfer rate of the symbols transmitted do not exceed the Nyquist rate. Thus with 4-QAM (four level QAM) the theoretical efficiency is 2 b/s/Hz. Thus, assuming perfect filtering a 9.6 kb/s data rate signal could be transported over a 4.8 KHz occupied channel bandwidth. This means that under the current FCC proposal., the 9.6 kb/s information rate signal could fit within a 6.25 KHz channel but with an occupancy of 4.8 KHz it would not fit within a 4.0 KHz occupied bandwidth. One solution to the dilemma is to make authorized channel bandwidth and occupied bandwidth values the same whilst still mandating acceptable emission masks. These relationships are presented in Table-2:

TABLE-2

Modulation	Theoretical B/W Efficiency	Attainable B/W Efficiency
4-QAM	2 b/s/Hz	2 b/s/Hz
16-QAM	4 b/s/Hz	3.8-4 b/s/Hz
64 QAM	6 b/s/Hz	5.7-6 b/s/Hz

Thus, referring to Table-2, 16 QAM would have a maximum theoretical bandwidth efficiency of 4.0 b/s/Hz. The 64 QAM mode, then would have an information capacity of 6.0 b/s/Hz. In the Commission's proposed occupied bandwidth of 4.0 or 5.0 KHz, effective data rates of at least 22.8 kb/s are achievable with 64 QAM.

For realizable QAM systems, the relationship between bandwidth efficiency and power requirements in terms of carrier-to-noise ratio in a double sided Nyquist bandwidth that equals the transmit symbol rate, for a 10^{-6} bit-error-rate (BER) are presented in Table-3:

TABLE-3

QAM Bandwidth Efficiency	Carrier-to-Noise (CNR) Ratio Required
4-QAM @ 2 b/s/Hz	14dB
16-QAM @ 4 b/s/Hz	20 dB
64-QAM @ 6 b/s/Hz	26 dB

Thus, from Table-3 it may be seen that while the power efficiency of binary or even 4-ary signaling is fairly good, very high bandwidth efficiencies pay the price of significant increases in power. In this example, if one were to initially employ 4-QAM and migrate to 16-QAM, to effect the same error performance, a 6.0 dB (factor of four) increase in power is required.

Compare the results of Table-3 with the Shannon theoretical limit presented in Table-1, and it becomes obvious that significant improvement in coding efficiency are needed to operate at or near the Shannon limit. For example, with 16-QAM, at a bandwidth efficiency of 4 b/s/Hz the required CNR is 20 dB, for systems operating at the Shannon limit, 4 b/s/Hz the Theorem states that a CNR of only 12 dB is required. In practice therefore, with advanced techniques we still are many dB's (in the case of 4 b/s/Hz a minimum of 6 dB) removed form the theoretical limit. Remember too that the values in Table-l are for "error free" transmission whilst the practical values in Table-3 are for a BER of 10^{-6} , which while respectable, is certainly not error free.

Detractors of narrowband and bandwidth efficient technologies represent that a mobile communications channel is characterized by phase and amplitude distortions of such a degree that they make the use of "high" level very bandwidth efficient modulations , such as 16 QAM or better, impossible.

Such positions are indefensible and ignore the tremendous advancements in phase and amplitude perturbation correction made over the last twenty years, that permits a complex Rayleigh/log normal channel to become a first order time invariant Gaussian channel. Such channel linearization techniques as Feed Forward Signal Regeneration (FFSR) and Transparent Tone In-Band (TTIB), developed in the early 1980's by Dr. Joseph McGeehan and Dr. Andrew Bateman, are the best examples today of such practices and are proven in their effectiveness.

In McGeehan's 1980's FFSR/TTIB research, using 16 QAM modulation very low error (10^{-6} BER) transmission at approximately 13 kb/s in a 3.4 KHz occupied bandwidth, was demonstrated at 400 MHz under Rayleigh faded conditions approximating a vehicle velocity of approximately 100 km/h. McGeehan obtained this performance level without the use of any error detection and correction (EDAC) and simply relied upon the FFSR/TTIB channel linearization techniques to provide a solid time invariant channel.

V. BANDWIDTH & SPECTRALLY EFFICIENT TECHNOLOGY PROLIFERATION AND UTILITY DEMANDS FLEXIBLE POWER AUTHORIZATION

With this Spectrum Refarming NPRM the Commission is proposing dramatic reductions in permissible effective radiated power levels. This approach, in our judgment is ill advised at best because the arbitrary limitation of power whilst concomitantly requirement and ostensibly promoting bandwidth efficiency is technically unsound. As will be discussed below, the Shannon channel capacity theorem is clear in this regard, improved bandwidth efficiency DEMANDS increased power. Likewise Nyquist addressed the issue of symbol detection and hoe to avoid inter symbol interference.

The Commission's assumptions regarding desired to undesired ratios are therefore technically indefensible. The desired to undesired ratio is a function of the bandwidth efficient modulation technique employed and such parameters as diversity improvement and channel linearization/normalization technique employed and the detection technique used.

Comments filed by Motorola referencing those of the Land Mobile Communications Council fail to consider the impact of bandwidth efficient technology insertion and the concomitant increase in power levels needed to accrue comparable operational benefit.

The manufacturing community as a whole appears to shun bandwidth efficiency as being too costly. The arbitrary limitation on power levels independent of considering the bandwidth efficient techniques employed will only serve to prove correct manufacture claims that INCREASED bandwidth is the solution .

VI. FLEXIBLE POWER AUTHORIZATIONS MANDATE MANUFACTURER DISCLOSURES

Manufacturers must provide quantitative data addressing such parameters to assist system designers establish the needed system power budgets including antenna heights and effective radiated power levels. Likewise, the requirement to mandate manufactures to provide quantitative data concerning their equipment's performance will enable frequency coordinators to establish suitable BANDWIDTH **EFFICIENT TECHNOLOGY SPECIFIC** service and protection contours.

As a condition of type acceptance we propose that the Commission require manufactures to disclose technology specific details needed to facilitate frequency and interference management. These technical details must address the carrier-to-interference or desired-to-undesired and adjacent channel protection ratios needed for the technologies manufacturers expect to market, With this information, frequency coordination bodies would be in a position to coordinate systems employing disparate channel access and modulation techniques affording the needed protection ratios to each specific entity.

This posture requiring disclosure will promote the deployment of highly efficient technologies and innovative application of emerging technologies.

VII. EFFICACIOUS USE OF BANDWIDTH EFFICIENT TECHNOLOGIES MANDATE FLEXIBLE BANDWIDTH OCCUPANCIES AND EMISSION MASKS

We take exception to the Commissions proposal to limit authorized bandwidth to approximately 80% of the channel spacing or authorized bandwidth. Given the advancements in communications technology and the need to promote substantive increases in spectrum use efficiency vis-a-vis the proliferation of bandwidth efficient technologies, it is in the public interest to permit full utilization of available channel bandwidth.

Current technologies will allow for the suppression of out of band intermodulation products by at least 75 dB through the use of linearized amplifiers employing DSP based feed forward control. In addition, current DSP based filtering technology will permit the practical implementation of “brick wall” rectangular/Nyquist filters.

In addition, with the imposition of very stringent, but practically realizable, frequency control and stability requirements on subscriber equipment the need for “guard band” allocation is unnecessary. For example, automatic frequency control based upon sample and hold AFC techniques employing traditional high stability or atomic reference standards could provide subscriber sets with frequency stabilities comparable to that of fixed equipment that is otherwise unattainable.

However, for those systems whose operational requirements do not dictate the use of the full authorized bandwidth, the Commission’s proposal for 80%, with the proposed technical parameters concerning emission mask and frequency stability could remain.

Thus the promulgation of FLEXIBLE standards permitting full, that is 100% channel bandwidth occupancy (or 6.25 KHz) under certain specific conditions is not only highly desirable, it is practicable and in our judgment essential to promote technology advancement.

Such technical conditions under which "100%" occupied bandwidth should be authorized must require extremely stable frequency tolerances and rectangular filter shape factors that assure that the 100% occupied bandwidth has a spectral attenuation at the edge of the authorized bandwidth consistent with the Commissions NPRM parameters.

The bottom line is that the technical parameters adopted MUST promote the implementation of these bandwidth/spectrally efficient technologies.

We therefore propose the Commission permit authorize bandwidth, defined as containing those frequencies upon which 99% of the radiated power appears, extended to include any discrete frequency upon which the power is at least 0.25 % of the total radiated power, to be equivalent to the "channel spacing" or "authorized bandwidth if the frequency stability of the system is kept to that specified for the fixed station infrastructure. Attenuation at the edge of the authorized channel where the authorized channel and authorized bandwidth are equivalent should be specified at 50 dB down at the edge of the authorized bandwidth of the adjacent channel. Thus if an adjacent channel 6.25 KHz channel requested an authorized bandwidth of 5.0 KHz the channel with an authorized bandwidth of 6.25 KHz in a 6.5 KHz channel would have to be 50 dB down .625 KHz removed from the 6.25 KHz authorized bandwidth channel edge. Likewise, if adjacent 6.25 KHz channels both employed 6.25 KHz authorized/occupied bandwidths, at the channel edge signals must be 50 dB down necessitating the use of rectangular "brick wall" filtering technology and very low distortion amplifier techniques.

VIII. NARROWBANDING WILL NOT CAUSE INTERFERENCE TO MILLIONS OF EXISTING USERS

Claims of causing harmful interference to “millions” of users as stated by Motorola and others is unwarranted. These analyses appears to make the erroneous assumption that narrowband technology will be inserted in a uncoordinated and haphazard manner and in such an ambitious fashion that will preclude the changeout of existing users equipment.

However, assuming the Commissions proposals are adopted in toto, it is unreasonable to assume that narrowband will proliferate at a rate that can not be managed through the frequency coordination process. Likewise, the same manufacturing constituency that raises the specter of universal interference also states that the current art is not ready to produce the narrowband equipment. In either case this is a non-issue. If manufactures are correct that the art will not support widespread narrowband production today, then only limited quantities of narrowband equipment will be fielded and the rate of fielding will be gradual permitting existing users to amortize their existing equipment base.

We are confident that the frequency coordination process, assuming it is provided with the appropriate information from the manufacturing community, will be able to facilitate the insertion of these technologies in a fashion as to minimize any interference caused existing users. Additional details relating to systems engineering are provided in Appendix-A to these Reply Comments.

Finally, narrowband transition must be just that a transition, based upon the frequency coordination process considering the minimization of interference to existing users.

IX. EXTENDED NARROWBAND TRANSITION/MIGRATION SHOULD ONLY BE AFFORDED TO PUBLIC SAFETY LICENSEES

We support the Commissions strategy to require the reduction in modulation index to effect a channel occupancy of 10 KHz to create spectral “gaps” that may be used to permit the insertion of narrowband technology.

We oppose the majority of comments filed by the manufacturing community that advocates an extended migration term for all spectrum users.

It is our opinion that based upon current equipment fielded, relatively simple modifications are required to “narrowband” detection systems so that the system noise performance is maintained.

We also propose that a uniform channelization be specified for ALL private radio services not limited to those below 512 MHz but including all current 800-900 MHz and future "L" band and above usages.

However, we strongly suggest that in the Public Safety services, public safety entities who operate encrypted equipment employing F3E or F9E emissions be permitted to continue said operations for some unspecified, indefinite period of time. Most encrypted public safety systems especially those interoperable systems which comply with the Office of National Drug control Policy’s National Telecommunications Master Plan for Drug Enforcement, employ digital emissions that are NOT amenable to broad scope narrowbanding. These NTMPDE drug enforcement interoperable systems are encrypted with the Data Encryption Standard (DES) cryptographic algorithm operating in the single bit cipher feedback mode (CFB) and employ continuously variable slope delta modulation (CVSD) at a bit rate of 12.0 kb/s and is transported via binary frequency shift keying (FSK). While this technology is old, it is currently and is anticipated to remain the mandated STANDARD for drug law enforcement interoperable communications. Various estimates place the public safety investment in this technology in the area of 900 million dollars. To preserve the operational integrity of these systems, their instantaneous frequency deviation is set to 4.0 KHz. with an equivalent modulating frequency of 6.0 KHz (corresponding to a transmitted data rate of 12.0 kb/s via binary FSK) bandwidth occupancy is approximately equivalent to 5.0 KHz deviated analog voice and necessitates the use of a 25/30 KHz channel. It is NOT possible to reduce the instantaneous frequency deviation of these 12.0 kb/s encrypted digital voice with out destroying the range and operational performance of these systems. In addition, any tampering with the 12.0 kb/s operational parameters will render those systems in place with state and local law enforcement non-interoperable with federal agencies who almost exclusively employ 12.0 kb/systems for all operational traffic not limited to drug law enforcement.

We propose the Commission grandfather the Pubic Safety use of 12.0 kb/s encrypted digital voice systems, until such time as a new national standard is adopted and subject to state and local agency funding/budgetary replacement cycles

X. UNIVERSAL AUTHORIZATION OF CDMA/DSSS AND FREQUENCY HOPPED SPREAD SPECTRUM OVERLAY

Reference Spread Spectrum Operations 88.491 we reiterate our position that spread spectrum and other wideband technologies should be encouraged to the greatest extent feasible, with a minimum of governmental restraints and regulation.

However, we believe the proposed action by the Commission does not go far enough to encourage the development and application of wideband technology.

Unlike the proposal advanced by GEC MARCONI, which limits CDMA overlay only to those applications requiring a Low Probability of Intercept capability and requiring a minimum of 1 MHz of contiguous spectrum, we propose that ALL services currently licensable under the existing Part 90 be afforded the option to utilize spread spectrum or other broad band technologies.

The Commission should take affirmative measures to encourage the proliferation of technology relevant to public communications privacy and security through a relaxed regulatory posture, specifically as it applies to spread spectrum and other broadband emissions employing covert waveforms.

Thus, the general authorization, on a non-interfering basis, of wideband and spread spectrum emissions employing covert waveforms to all licensee categories will be an important step.

Licensees, and the public in general, should have equal and ready access to technologies that may enhance their competitive posture through affording secure and jam resistant communications. In addition the use of spread spectrum and other suitable wideband techniques will afford heretofore unrealizable gains in spectrum use efficiency though permitting the universal overlay of vast blocks of spectrum.

In the case of proposed part 88 technical standards pertaining to spread spectrum emissions, we suggest hat effective radiated power for frequency hopped systems be linked to their hop rate, dwell time, number and distribution of hopping frequencies. With direct sequence spread spectrum and other wideband systems employing covert waveform technologies, power must be expressed in terms of a spectral power density normalized over a given occupied bandwidth.

For frequency hopped systems, we suggest mandating the hoping sequence follow a rectangular distribution in a pseudo-random fashion and mandate maximum channel dwell time of 10 m/s. Effective radiated power levels should be tied to both dwell time and the number of discrete hopping frequencies where frequencies are separated by at least 30 KHz. A maximum instantaneous effective radiated power of 15 Watts appears reasonable at a dwell of 20 m/s over 10 hopping frequencies. ERP levels of 150 Watts should be permitted in systems that employ a dwell time of 1 m/s or less and hop over 100 or more discrete frequencies. These values will provide for impulses that are generally outside of the integration times of most detection systems.

In the case of direct sequence spread spectrum, 10.0 mW/KHz or 1 .O x 10 exp. -5 W/Hz is a reasonable value for general overlay over all Part 88 spectrum. Thus specifying a Spectral Power Density of 1.0x1 0 exp. -5 W/Hz a DSSS station operating at an effective radiated power level of 100 Watts would require a spreading function of 1 .O x 10 exp. 07 Hz or 10 MHz bandwidth.

XI. CONCLUSIONS

As stated in our initial filing, new and innovative wireless techniques will continue to place increasing demands on the spectrum resource necessitating the long term implementation of both bandwidth and spectrally efficient technologies to improve the overall use efficiency of our radio frequency spectrum resource.

With the proliferation of digital signal processing, low cost application specific integrated circuits (ASIC) and monolithic microwave integrated circuitry, an opportunity exists to significantly advance the use efficiency of all wireless spectrum usages.

With spectrum refarming comes the “great” promise...the expansion of available discrete channels by between 300 and 500 % in the affected bands. However, is increased channel availability the real benefit of this major anticipated action? We think not.

We believe that the real promise of refarming is the stimulation of advanced digital communications technology that will revolutionize the personal communications industry as we know it today. Unfortunately, the proposed regulations contained in the NPRM will in effect stifle the proliferation and exploitation of the most viable bandwidth and spectrally efficient technologies through continuing to support antiquated and incorrect beliefs concerning the fundamental nature of spectrum efficiency, and by a failure to effectively consider the fundamental physics predicate to all communications.

However, if bandwidth and spectrally efficient technologies are stimulated and incentivized, one of the many benefits likely from the proliferation of advanced digital communications technology is the provision of fully imbedded signaling and integrated transmission of both voice and multi-media digital data.

The Commission today has a unique opportunity to adopt a highly proactive technology stimulative posture that will facilitate the development and deployment of virtual seamless information transport capabilities predicated upon wireless technologies. We encourage the Commission to proceed post haste.

APPENDIX -A

SYSTEMS ENGINEERING CONSIDERATIONS

The digital and analog worlds represent distinctly different considerations relative to the practical implementation and use of technologies. In analog practice, issues such as phase distortion and frequency offset are present but in many instances may be ignored. However, in the digital world, preserving the integrity of system timing, phase and amplitude coherency is often an a absolute requirement.

For example, in analog systems we typical engineer from a system power budget perspective considering gains such as effective radiated power and effective detection system sensitivity; , and losses such as mean propagation loss and the appropriate correction factors. System reliability is defined in terms of maintaining some specified signal level, equivalent to some quality metric such as 20 dB S.I.N.A.D., for some given reliability such as 99% of the time over some prescribed area of coverage i.e. 99% of the area with in a 20 mile coverage contour.

In these instances analog systems make use of a flat (non-frequency selective) fade margin where-by some power budget margin, i.e. 30dB, above the signal mean will provide the desired reliability a the desired signal quality metric. However, the use of a “flat” fade margin in digital wireless systems is a meaningless concept when considering the bit-error-rate behavior of a digital wireless system. This is because the frequency-selective behavior of multipath attenuation results in an error ratio greater than that which would be caused by nonselective attenuation of the same mean signal amplitude.

Under this scheme the proposed emission masks will provide 40 dB of attenuation at the edge of the authorized channel (not bandwidth), 50 dB of attenuation at the edge of the authorized bandwidth of the adjacent channel, and 65 dB of attenuation thereafter.

Now of course, the proposed narrower FDMA channels do not mandate the use of digital technologies. And , depending upon how the power level issue is resolved, analog single side band may prove to be the only really viable technology. In fact, single sideband in the form of in the form of amplitude companded single sideband (ACSSB), a fifty year old technique, is a likely and potentially aggressive candidate that may provide for cost effective narrowband communications in these narrower channels. ACSSB (actually amplitude companded double sideband) was initially used for handling transatlantic telephone traffic in the 1930's and its operational parameters and capabilities are well known. But so too are various digital techniques.

However, we anticipate that to economically implement bandwidth efficient techniques that can support reasonable data rates such as 9.6 kb/s in a 4/5 KHz occupied bandwidth vendors will be utilizing a linear system architecture.

Thus, we may use DSP based direct conversion or up conversion linear frequency translation in concert with high level digital modulation such as 16 Quadrature Amplitude Modulation (QAM), and employ certain adaptive channel linearization techniques as McGeehan's Transparent tone In-Band (TTIB) with Feed Forward Signal Regeneration (FFSR). The result being a very bandwidth efficient digital implementation. Being a direct liner frequency conversion bandwidth occupancy at radio frequency that is proportional to the baseband bandwidth, which has been frequency translated. Of course RF. power amplifiers are analog devices but if the